NDE OF CORROSION AND DISBONDING ON AIRCRAFT USING THERMAL WAVE IMAGING

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INTRODUCTION

Thermal wave imaging has been shown to have the quantitative capability for measuring aircraft skin corrosion thinning. [1] For single fuselage skin, the technique is sensitive to less than 1% material loss, and can make rapid (a few seconds) measurements which compare well with direct micrometer readings. The method uses pulse heating of the aircraft by means of photographic flashlamps which are enclosed in a metal shroud to trap and funnel the light uniformly onto the surface during the 5msec duration of the pulse. An infrared (IR) focal plane array camera, aimed and focused at the surface through an opening in the rear of the hand-held shroud, monitors the rapid cooling of that surface following the pulse. Metal doublers, bonded to the inside surface of the fuselage, cause the outside surface just above them to cool more rapidly, whereas regions which are thinned because of internal surface corrosion cool less rapidly. By appropriate selection of the gate time(s) for monitoring the cooling, these features show up as distinct dark (light) features in the resulting thermal wave images. The system we have developed at Wayne State University has the electronics and computer mounted on a two-wheeled cart, and the imaging head (shroud/lamps/camera) remotely located and connected to the cart by a long (50-ft) umbilical cable (shown in the photo from the FAA's Airworthiness Assurance Validation Center (AANC) hangar in Albuquerque, NM).

Fig. 1 Thermal wave imaging of a DC-9 testbed aircraft in the FAA's Aging Aircraft NDI Validation Center (AANC).

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CORROSION INSPECTION

One of the test objects in the AANC "library" is a Boeing 737 testbed, which is available for use in developing NDI methodologies. In Fig. 2 we show a thermal wave image from a region of lap splice on this testbed - a target which is rather more complicated than the single fuselage skin just above it. The number (20.4%) which appears in Fig. 2 is the result of applying the quantitative corrosion thinning algorithm [2] to the bright region indicated by the arrow. Because of the presence of the fasteners (heat sinks - black) and the second layer of metal involved in the lap splice construction, it is not clear that this algorithm should work without applying some correction factors relative to the situation for a region of single fuselage skin. Nevertheless, following our measurement, shown in Fig. 2, one of the AANC staff members utilized a standard eddy current corrosion thinning measurement instrument and indicated that the corrosion was approximately 20%. Although laboratory studies are still in progress, we find that the thermal wave estimates in such situations are likely to be somewhat less than the actually corrosion thinning, and somewhat dependent on the lateral size of the region of corrosion, and the thickness of the layer of paint on the outside of the aircraft (unless it is very small compared to the skin thickness).

A second example of aircraft corrosion is illustrated in Fig. 3, which shows a single thermal wave image of two adjacent steel fasteners in a wing skin sectioned from an Air Force KC-135 aircraft. Because of the contact between the dissimilar metals (Steel/Al), the interface region in the countersink surface of the aluminum wing skin is susceptible to pitting corrosion, which in some cases, progresses laterally out from the countersink in the form of intergranular corrosion cracking. In a test program conducted by ARINC for the USAF, we have applied thermal wave imaging to 80 such fasteners in both KC-135 and B-52 wing skins. We succeeded in identifying 87.5% of the fasteners with confirmed intergranular corrosion (some of it quite minor, as seen in the metallographic optical imaging sections following the test), with zero false calls. In Fig. 3, two thermal wave images from this test are displayed, the left showing corrosion, the right showing uncorroded material.

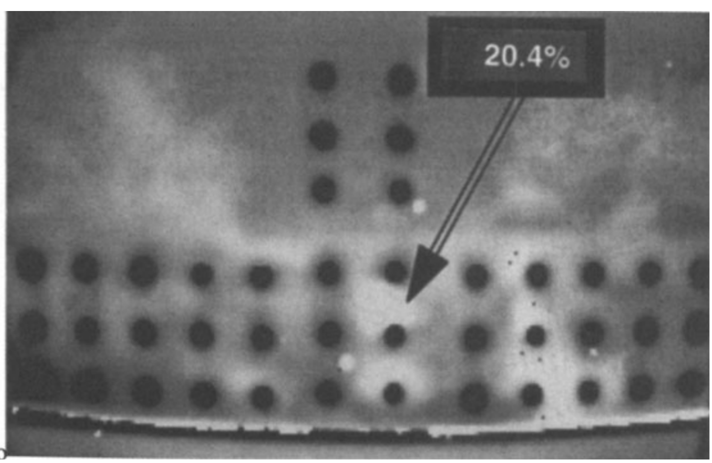

Fig. 2 Thermal wave image of a region of corroded (about 20%) lapsplice on the B737 testbed aircraft in the FAA's Aging Aircraft NDI Validation Center (AANC). The estimate (20.4%) is obtained from the thermal wave imaging corrosion analysis algorithm, known to be accurate for single skins [1], but likely to underestimate the corrosion for small lateral sizes of corrosion and for regions with thick paint.

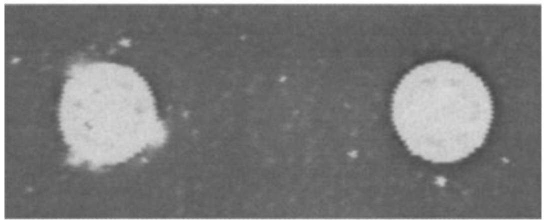

Fig. 3 Thermal wave image of two adjacent steel fasteners in a wing skin sectioned from an Air Force KC-135 aircraft. The left fastener shows several regions of intergranular corrosion, extending laterally from the top of the fastener head which "shadows" the corrosion. The indistinct nature of the thermal wave reflections from the lateral subsurface corrosion is typical of the thermal blurring expected from subsurface defect scattering.

INSPECTION OF BONDED DOUBLERS ON 747 AIRCRAFT

Another useful application of thermal wave imaging for aircraft inspection is to identify regions of disbonded doubler structures. Working together with representatives from the manufacturer and the airline, we have used thermal wave imaging to inspect Section 41 on three separate Boeing 747 aircraft. Two of these inspections took place during regular maintenance checks by the carrier, and the third took place on an airstrip at one of the manufacturer's sites. Figure 4 illustrates two thermal images taken from different B747 aircraft during the course of these tests. The left image shows the usual situation, in which the doublers are well bonded, showing up as cooler (darker gray) regions which are more or less symmetrically located with respect to the fasteners (black/cold circles). As noted above, the cooling results from the good thermal contact through the adhesive to the metal doubler below. The "gaps" in the horizontal structure on either side of the vertical doubler are part of the intended construction of the doubler, and therefore not indicative of disbonding there. Most of the structure on the right-hand thermal wave image in Fig. 4 is also well-bonded, with the exception of the region of the horizontal doubler extending to the left in this image. Thermal wave images of a region adjacent to that to the left of Fig. 4 (b) showed that the disbonded doubler extended throughout this short section of doubler. The same conclusion was drawn from traditional bond-testing apparatus, in measurements conducted during the same test by inspectors

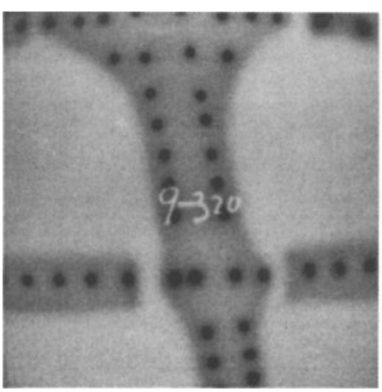

Fig. 4 (a) Thermal wave image of a well-bonded region of subsurface doubler from Section 41 of a B747 aircraft.

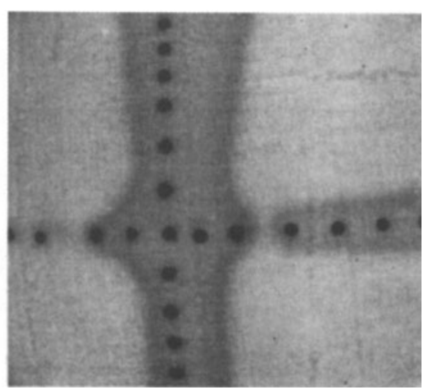

Fig. 4 (b) Thermal wave image of a disbonded region (left/center of the image) of subsurface doubler from Section 41 of another B747 aircraft.

from the airline and the manufacturer. The two methods agreed throughout the tests with one exception. One region, initially found to be disbonded by traditional testing, seemed well bonded thermally. Re-inspection by the manufacturer/airline confirmed the conclusion of the thermal wave imaging inspection.

CONCLUSION

Thermal wave imaging is progressing to the level of quantitative NDE capability for the problems of inspecting aircraft for corrosion and disbonding.

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